APPENDIX C

REMEDIAL, TREATMENT, AND CLOSURE TECHNIQUES

This appendix describes potential remedial, treatment, and closure action techniques and their applicability to existing waste sites on the Savannah River Plant (SRP). It also provides the basis for identification of remedial and closure actions associated with the existing waste site alternatives described in Sections 2.2.2 and 4.1 and assessed in this environmental impact statement (EIS).

The alternatives for the modification of waste management activities at existing waste sites are as follows:

- Removal of waste to the extent practicable at all waste sites, and remedial and closure actions, as required

- Removal of waste to the extent practicable at selected sites, and remedial and closure actions, as required

- No removal of wastes, but remedial and closure actions, as required

- No action; that is, no removal of wastes and no remedial and closure actions

The principal remedial, treatment, and closure actions potentially associated with these alternatives are the following:

- Groundwater pumping and possible chemical or physical treatment of recovered groundwater

- Treatment of hazardous waste as a limited treatment application

- Surface sealing and capping as a closure action

Hundreds of engineering concepts and actions are available for the treatment of wastes, for the remediation of waste sites, and for closure actions, although their feasibility has not been determined. The techniques described in this appendix either have been initiated or are considered to be both technically and economically attractive to the U.S. Department of Energy (DOE) for existing waste site remediation. The descriptions of techniques for potential remedial actions are derived from two handbooks published by the U.S. Environmental Protection Agency (EPA, 1982; 1985). This EIS does not select any specific remedial, treatment, or closure technique. DOE plans to conduct studies involving groundwater monitoring and modeling and the feasibility of approaches to establish firm remedial actions; the basis for these studies will be an alternative strategy selected by DOE.

Section C.1 describes corrective (remedial) actions, including permeable bed treatment, groundwater pumping, and impermeable barriers, and their applicability. Section C.2 describes the direct treatment of wastes and includes general information on biological, chemical, and mechanical techniques for waste treatment; it also addresses the applicability of these techniques to

SRP waste types. Section C.3 addresses closure actions, such as surface sealing and capping, water diversion and control systems, and leachate control systems. Section C.3 also describes the applicability of the closure actions to existing SRP waste sites.

C.1 CORRECTIVE ACTIONS

Corrective actions for dealing with groundwater contaminated by waste disposal sites are complex and dependent upon many variables. Many variables are site-specific, including local topography, geology, surface-water and groundwater hydrology, and existing and proposed future site development.

Corrective actions for dealing with contaminated groundwater include the following: (1) *in situ* treatment; (2) groundwater pumping; and (3) containment or diversion. *In situ* treatment is a method by which contaminated groundwater is allowed to flow through permeable treatment beds (e.g., activated carbon). The beds are installed vertically below the ground surface and are designed to filter contaminants. Groundwater pumping is used to remove contaminated groundwater for treatment, contain a groundwater plume, or lower the groundwater so it does not contact the waste disposal area and become contaminated. Containment or diversion is the installation of impermeable barriers. These barriers are positioned below the ground surface to either prevent groundwater from migrating away from the site (containment) or divert groundwater and prevent contact with waste materials (diversion). Although the following paragraphs describe the corrective actions individually, an effective design often combines two or more actions.

C.1.1 PERMEABLE TREATMENT BEDS

C.1.1.1 Description

Permeable treatment beds are sections of porous media through which contaminated groundwater passes and which remove the contaminants through physicochemical processes. Installed vertically below the ground surface in a manner similar to, and often with, slurry walls, permeable treatment beds are a viable means of *in situ* treatment (see Figure C-1).

Construction of a permeable treatment bed entails excavating a trench to intercept the flow of contaminated groundwater, filling the trench with the appropriate materials, and capping it. The trench extends to a confining layer at some depth below the ground surface. Permeable treatment beds are economical where the water table is close to the surface, and the aquifer is shallow with bedrock or a confining layer limiting the depth to which the fill must be placed. The width of the trench is determined by the velocity of the groundwater flow, and the contact time required for effective treatment. Finally, the trench must be long enough to contain the plume and prevent it from circumventing the treatment beds.

The following materials are used in permeable beds to remove contaminants from groundwater: (1) crushed limestone or crushed shell; (2) activated carbon; (3) glauconitic greensands or zeolite; and (4) synthetic ion exchange resins. Each of these materials is effective for the removal of specific contaminants;

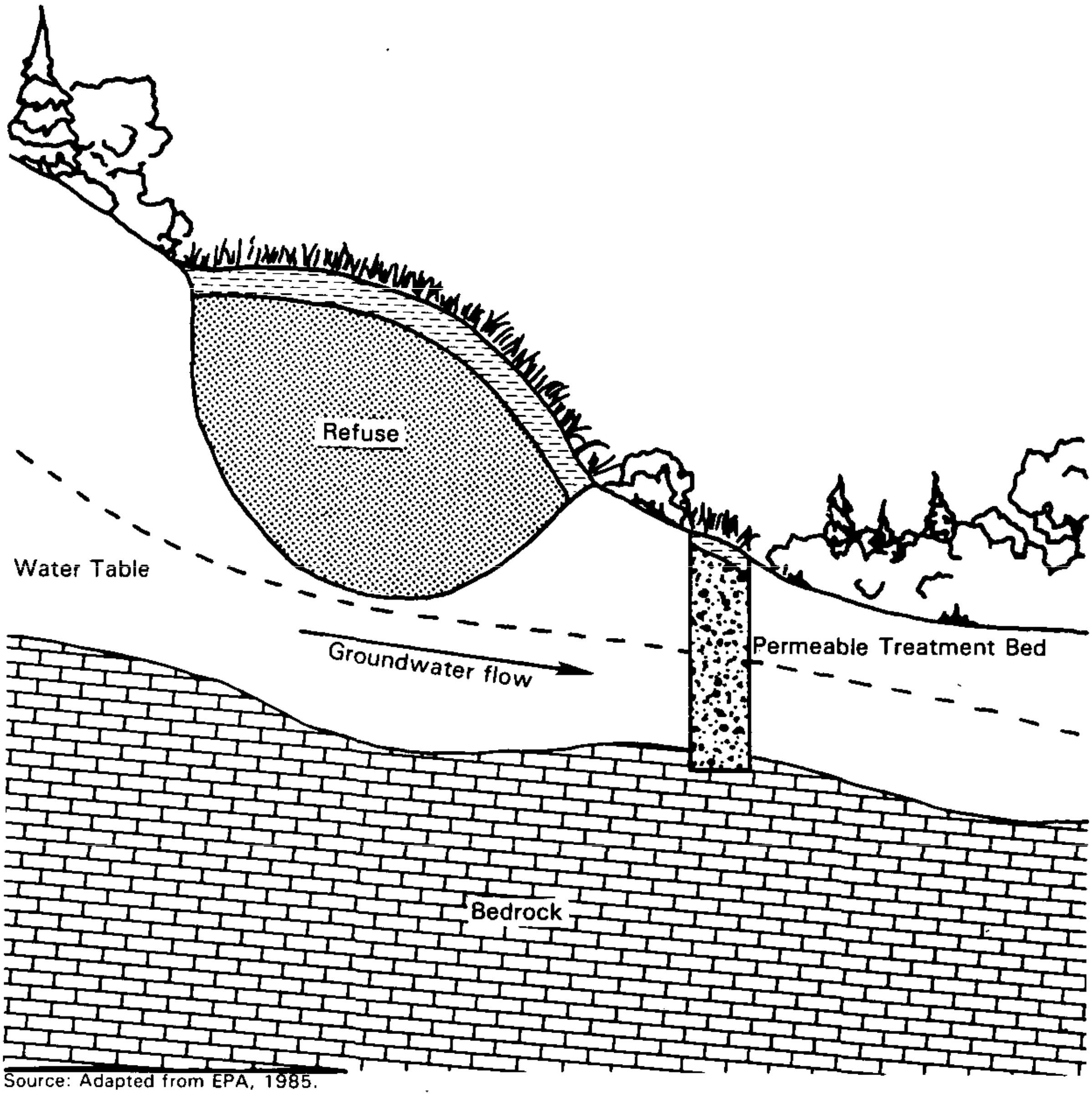


Figure C-1. Installation of a Permeable Treatment Bed

however, they are limited in service life to varying degrees and must eventually be replaced or regenerated.

Crushed Limestone

Permeable treatment beds of crushed limestone contain granular materials varying from gravel- to sand-size particles. The particle size used depends on the results of the analysis of the type of soil in which groundwater flows and the level of groundwater contamination. Limestone is used to neutralize acidic flow. It also can be used to remove metallic contaminants such as cadmium, iron, and chromium from groundwater.

Activated Carbon

Activated carbon is a carbon compound that has been heated without oxygen to activate its pores. This material, which generally is derived from coal or wood, varies from pebble to sand size; it is also available in powder form. Activated carbon is used to remove organic contaminants, such as carbon tetrachloride and polychlorinated biphenyls.

Glauconitic Greensands

Glauconite is a hydrous aluminosilicate clay mineral, rich in ferric iron and potassium. Glauconite occurs as dark, light, or yellowish-green pellets 0.9 to 1 millimeter long, as casts of fossil shells, as coatings and other grains, and as a clayey matrix in coarser-grained sediments. Glauconitic greensand deposits of the Atlantic Coastal Plain have a high potential for the removal of heavy metals from contaminated water. High removal efficiencies are reported for copper, mercury, nickel, arsenic, and cadmium.

Other Materials

Other materials that are used for removing contaminants from groundwater are zeolite and synthetic ion-exchange resins. These materials are effective in the removal of heavy metal contaminants but are seldom economical for permeable beds because of problems with short life, high cost, and regeneration.

C.1.1.2 Applicability

Permeable treatment beds have limited applicability on the SRP. The depth to groundwater at most of the waste sites is from 12 to 30 meters. The "green clay" is the first effective confining layer. It generally lies about 30 to 61 meters below the surface, except near Upper Three Runs Creek where it outcrops (see Sections 3.4.1 and 3.4.2).

C.1.2 GROUNDWATER PUMPING

C.1.2.1 Description

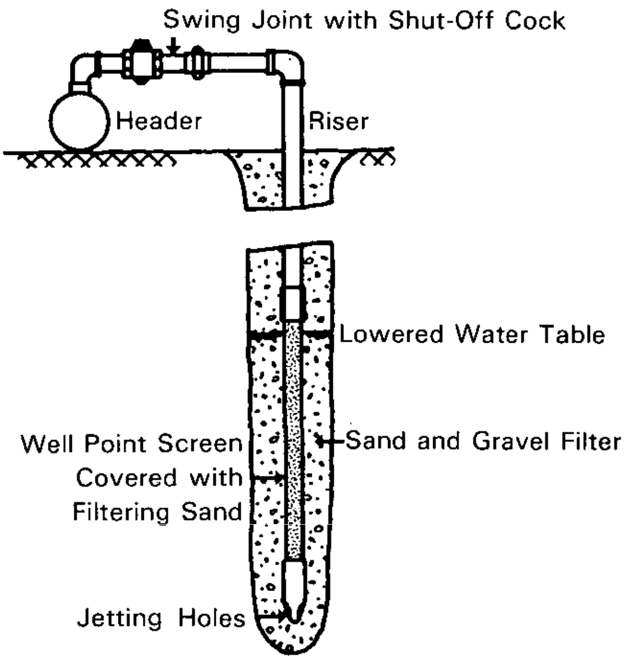
Groundwater pumping alters the elevation of the groundwater through the development of a cone of depression around the well. If wells are placed closely together, the combined cones of depression result in a depression network, which can lower the effective elevation of the groundwater over a large area. Groundwater pumping serves two purposes: it retrieves contaminated groundwater for treatment (Section C.2) and reduces further migration of the contaminants.

Groundwater pumping uses pumps to draw the groundwater to the surface through a series of wells. An adequate well system requires a careful evaluation of site conditions; a knowledge of seepage and groundwater flow to wells or wellpoints; and an understanding of wells, wellpoints, and pumping equipment. Any groundwater lowering (also referred to as dewatering) technology requires careful consideration of the possible effects of its implementation.

Wellpoints

Wellpoints are small well screens approximately 5.1 to 7.6 centimeters in diameter and 0.3 to 1.1 meters long. They are manufactured with brass or stainless-steel screens and with closed ends, drive-point tips, or self-jetting tips. Self-jetting-type wellpoints are installed in the ground with water flowing out the tip under high pressure. Closed end or plain tip wellpoints are installed into predrilled boreholes. Drive-point tips are installed directly via drop hammer and are suitable for some soils. Lines or rings of wellpoints installed on 0.9- to 3.6-meter centers and attached to a common header pipe (15 to 30 centimeters in diameter) and connected to a wellpoint pump (a combined vacuum and centrifugal pump) are called a wellpoint system (see Figure C-2).

Wellpoints are a common method of dewatering for construction purposes. They are applicable where the required depth of drawdown is no greater than 4.6 to 6.1 meters below the center of the header. Discharge capacity is generally on the order of 0.95 to 1.9 liters per second.



Source: Adapted from EPA, 1985.

Figure C-2. Well Point

Deep Wells

Deep wells differ from wellpoints by their function, which is to pump heavy flows over large vertical distances. These are typically large-diameter wells with diameters that range from 15 to 51 centimeters. Well screens typically range in length from 6 to 23 meters. Screens consist of a commercial-type water well screen or a perforated metal pipe often surrounded with a properly graded sand and gravel filter. Deep wells need 6- to 61-meter centers, depending on conditions. Pumping is performed with a submersible or vertical turbine pump installed near the bottom of the well. Well pumps are available in sizes from 0.3 to 379 liters per second, with head capabilities up to 183 meters.

Jet-Eductor Wells

Jet-eductor wells are wellpoints modified to provide lifts in excess of the typical 5- to 6-meter physical limits of standard wellpoints. Such a well is a wellpoint attached to the bottom of a jet-eductor pump, with one pressure pipe and a slightly larger return pipe.

Vacuum Wells

Vacuum wells are modified wellpoints or deep wells. The screen and riser pipe of a vacuum well are surrounded with a free-draining sand filter extending to within a few feet of the surface. The remainder of the soil is sealed with bentonite or impervious soil. The vacuum within the well effectively increases the hydraulic gradient toward the well or wellpoints.

Vertical Sand Drains with Wellpoints or Deep Wells

Vertical sand drains are used with deep wells and wellpoints to drain stratified soils where impermeable strata lay on top of more pervious strata. The drains are constructed by drilling vertical boreholes through the impermeable layers and are extended to underlying impermeable layers where wellpoints are placed. The boreholes, usually 41 to 51 centimeters in diameter, are continuously cased during advancement. The borings are filled with sand or other appropriate pervious material and the casings removed. A system of vertical sand drains is installed on 1.8- to 3.0-meter centers.

Sand drains with wellpoints or deep wells are applicable where a less permeable zone above a more pervious zone needs to be drained. The sand drains intercept the flow in the upper zone and drain it to the lower zone where the pressure is kept reduced by pumping from deep wells.

C.1.2.2 Applicability

Groundwater pumping is considered a viable method for recovering certain types of contaminated groundwater for treatment at the SRP based on previous experience with groundwater contaminants. Generally, deep wells with submersible pumps would be required. The capacity of each well is limited due to the rather low transmissivity of the tertiary aquifer in areas where contaminated groundwater has been identified. In the M-Area, for example, a system of 11 recovery wells is in operation. The recovered groundwater is routed to a 25-liter-per-second air stripper that removes volatile organic compounds.

In addition to this ongoing application, all potential groundwater remedial actions identified in Appendix F would apply such pumping to recover the groundwater for treatment. Groundwater pumping would also be used to prevent further migration of contaminants.

C.1.3 IMPERMEABLE BARRIERS

Impermeable barriers are underground structures designed to restrict groundwater. The term "impermeable" is used in the context that most common types of barriers are more appropriately labeled "low permeability" barriers. The subject of impermeable barriers is readily divided into two broad categories, configurations (Section C.1.3.1) and types (Section C.1.3.2).

C.1.3.1 Barrier Configuration

The configuration of the impermeable barrier is its vertical or horizontal position relative to the waste site. Configurations are called upgradient, downgradient, circumferential, keyed (fully penetrating), or hanging (partially penetrating). Impermeable barriers in use today include slurry walls, grout curtains, and sheetpiles. Table C-1 summarizes the configurations for impermeable barriers.

Keyed or Fully Penetrating

Keyed impermeable barriers are designed to block flow from passing through the area in which they are located. They are vertical structures that are carried from the ground surface to a confining stratum or impervious layer at some depth. The barrier structure is "keyed" into the confining stratum, as shown in Figure C-3.

Hanging or Partially Penetrating

Hanging impermeable barriers are not keyed into a low permeability confining stratum. This configuration is generally used to control lighter-than-water contaminants such as petroleum products, which float on the top of the groundwater. The depth of the barrier depends on several variables, including the thickness of the floating contaminant layer and the anticipated lowest possible water table elevation.

Circumferential Placement

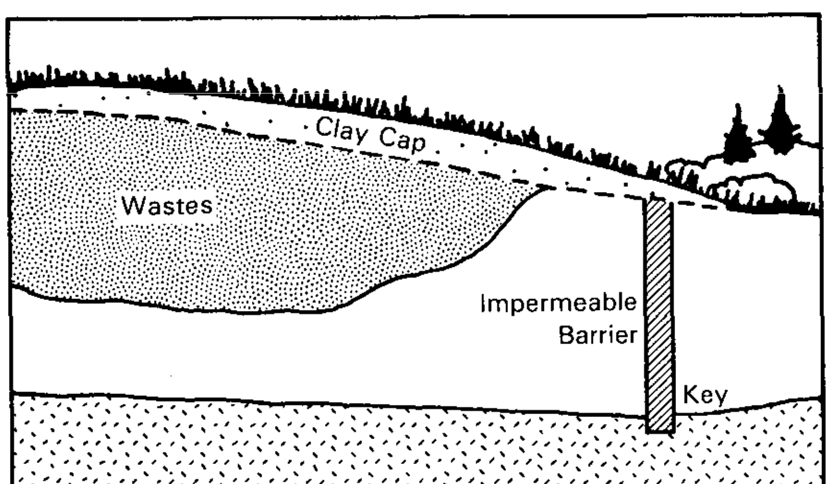
In circumferential placement, an impermeable barrier is installed completely around a waste site. With a cap and a leachate collection system, this barrier can reduce or eliminate the migration of contaminants.

Upgradient Placement

Upgradient placement is the positioning of the wall on the groundwater source side of a waste site. This type of placement is used to divert contaminated groundwater around the wastes where there is a relatively steep gradient across the site. Therefore, clean groundwater is prevented from becoming contaminated and leachate generation is reduced (see Figure C-4).

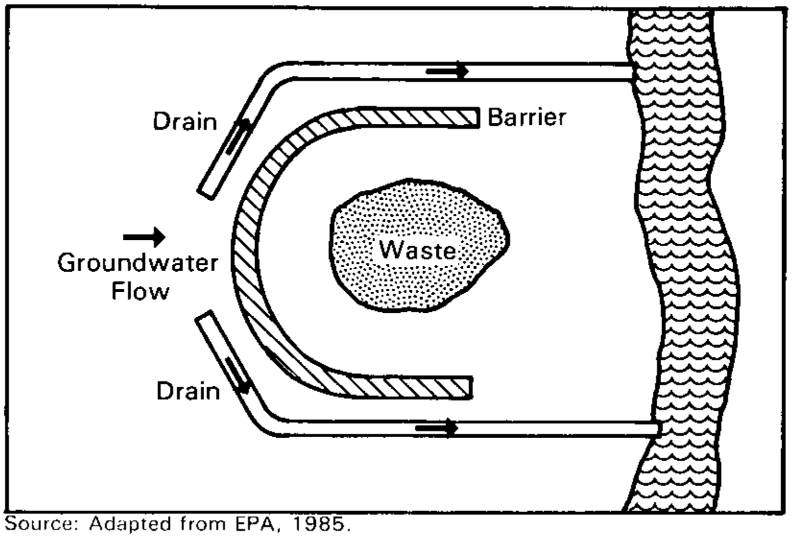
Table C-1. Summary of Configurations for Impermeable Barriers

Vertical Configuration	Horizontal Configuration: Circumferential	Upgradient	Downgradient
Keyed-in	• Most common and expensive configuration to use • Most complete containment • Vastly reduced leachate generation	• Not common • Used to divert groundwater around site in steep gradient situations • Can reduce leachate generation	• Used to capture miscible or sinking contaminants for treatment or use • Inflow not restricted, may raise water table
Hanging	• Used for floating contaminants moving in more than one direction (such as on a groundwater divide)	• Very rare • May temporarily lower water table behind it • Can stagnate leachate but not halt flow	• Use to capture floating contaminants for treatment or use • Inflow not restricted, may raise water table



Source: Adapted from EPA, 1985.

Figure C-3. Fully Penetrating Impermeable Barrier



Source: Adapted from EPA, 1985.

Figure C-4. Plan of Upgradient Placement with Drain

The design of upgradient barriers depends on site-specific variables. The actual site setting and the contaminants involved determine whether an upgradient wall can be keyed or hanging. Drainage and diversion structures might be needed to alter the flow of clean groundwater (see Figure C-5).

Downgradient Placement

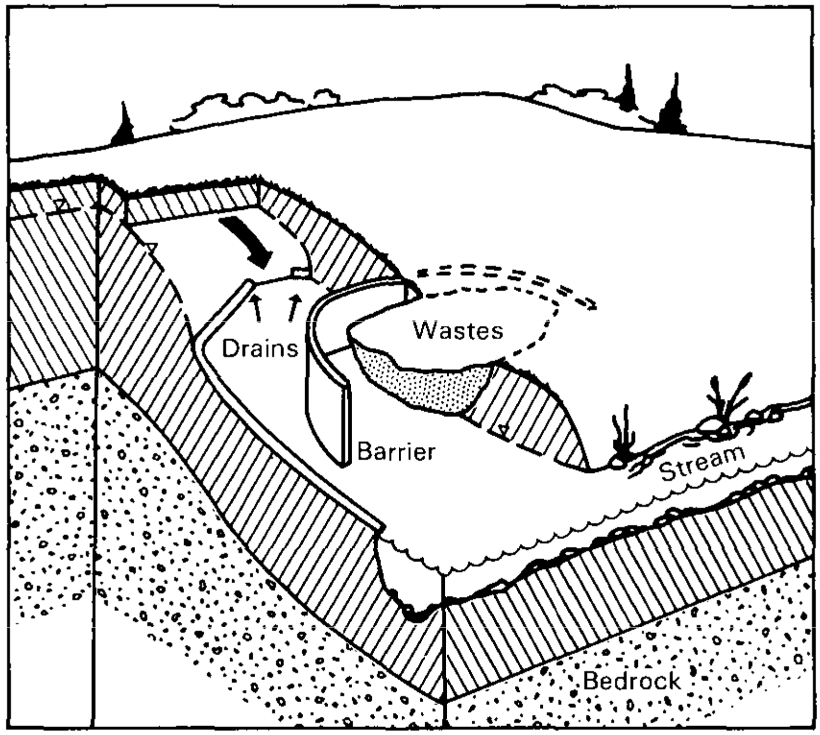
Installation of an impermeable barrier at a waste site at the side opposite the groundwater source is referred to as downgradient placement (see Figure C-6). The barrier serves as a temporary container of leachate and facilitates its easy recovery. Because it does not reduce the amount of groundwater entering the site, it is practical only in situations, such as near drainage divides, where there is a limited flow of groundwater. Without a means of recovery (i.e., deep wells or wellpoints), the volume of the barrier as a container would eventually be exceeded and contaminated groundwater would flow around the barrier and continue downgradient. Downgradient placement can use keyed- or hanging-type construction.

C.1.3.2 Barrier Types

The type of barrier chosen is a function of many variables, such as availability of materials, costs, required strength, and required permeability. Type and configuration are considered simultaneously and depend on the overall characteristics of each site.

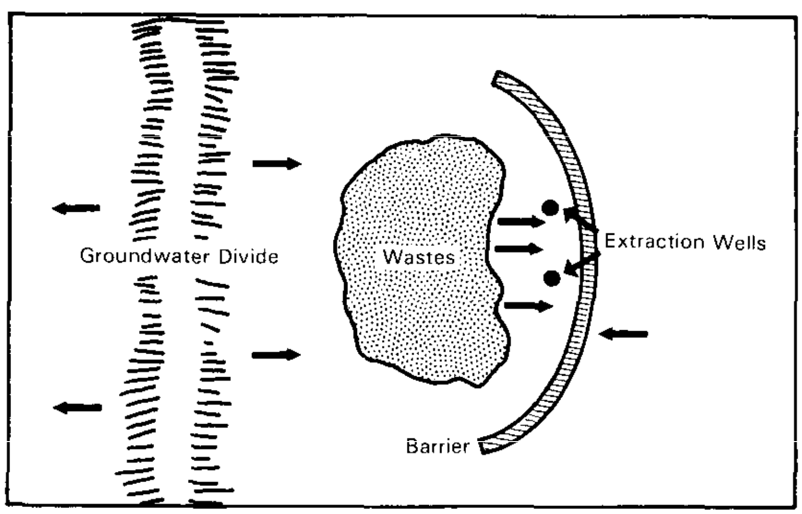
Slurry Walls

Slurry trench construction developed in the mid-1940s from the technology of clay-mud suspensions pioneered in oil well drilling operations in the early 1900s. Today, this practice covers a range of construction techniques from



Source: Adapted from Spooner *et al.*, 1985.

Figure C-5. Cut-away Cross-section of Upgradient Placement with Drain



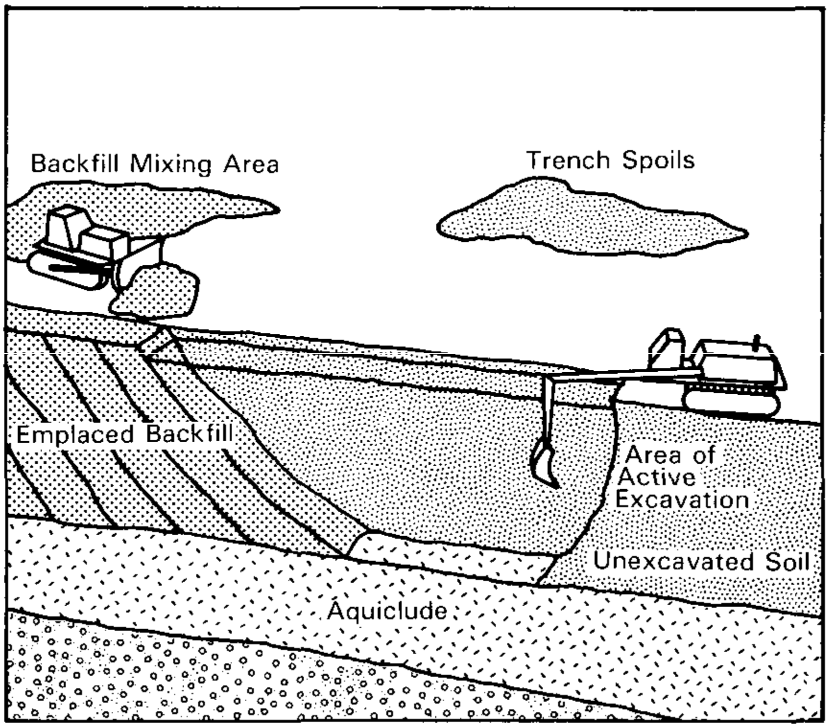
Source: Adapted from Spooner *et al.*, 1985.

Figure C-6. Plan of Downgradient Placement

simple to complex. In recent years, engineers and contractors have become aware of the low cost and nearly universal success of slurry wall cutoffs. This technique has largely replaced such methods as grout curtain and sheet piling cutoffs.

Two principal types of slurry walls, soil-bentonite (SB) and cement-bentonite (CB), are in common use. The names are derived from the key ingredients in the slurries used to construct each respective wall. Bentonite is a clay mineral that is highly expansive when combined with water; it can swell 10 to 12 times its original volume.

Slurry walls are constructed by excavating a trench to the desired depth; mixing a slurry of soil, bentonite, and water or of cement, bentonite, and water; and backfilling layers of the slurry (see Figure C-7). As the backfilling continues, the trench becomes completely filled with a monolith of soil or cement and bentonite of extremely low permeability.



Source: Adapted from Spooner *et al.*, 1985.

Figure C-7. Construction of a Slurry Wall

Grout Curtains

Grouting is the pressure injection of one of a variety of special fluids into a rock or soil body. These fluids set or gel into the rock or soil voids, greatly reducing permeability and increasing the strength of the previously ungrouted mass. Grouting of both soil and rock is a technology that has been used successfully for decades in the field of dam design and construction. The major use of curtain grouting is to seal voids in porous or fractured rock where other methods of groundwater control are impractical or likely to be ineffective.

Grouts can be divided into two main categories, suspension and chemical grouts. Suspension grouts contain cement mixed with fine particle materials, such as sand, clay, or bentonite. Chemical grouts consist of newtonian-type fluids, either natural or synthetic, manufactured and marketed under various trade names. Examples of chemical grouts include bituminous emulsions and sodium silicate with settling agents, accelerators, or hardeners.

The grouting process involves drilling holes to a predetermined depth below the ground surface and injecting grout with special equipment. A line of holes in single, double, or triple staggered rows is advanced vertically into the subsurface area. Grout is injected into every other hole to a predetermined depth; this is done until grout has been injected into each hole and the hole is filled (see Figure C-8).

Few data are available on the ability of the grouts to resist chemical degradation when contacted by contaminants. Special consideration should be given to the reaction of chemical grouts with the leachate. Testing should be conducted to determine these reactions before this grouting is used.

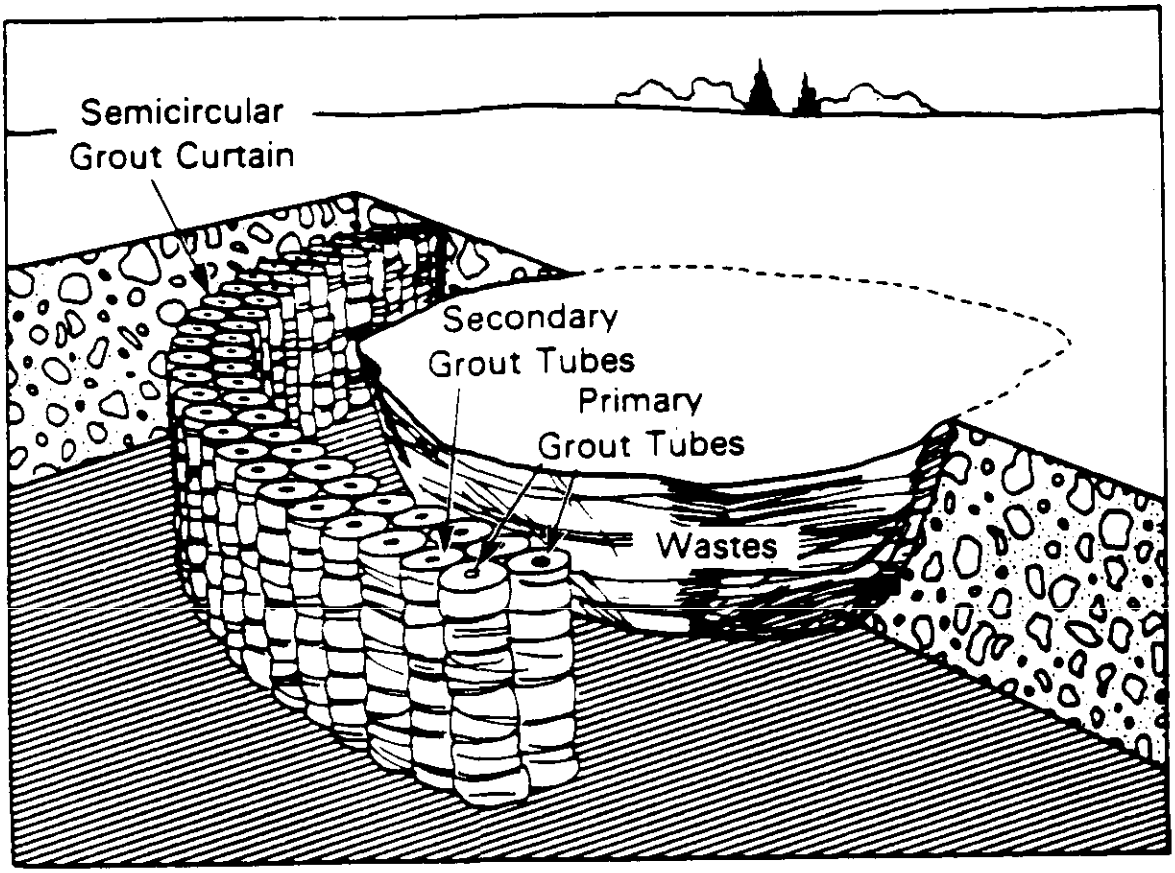
Sheetpile Walls

Sheetpile walls are narrow structural members that are driven below the ground surface mechanically to a desired depth. Sheetpiles, which are made of wood, concrete, or steel, serve a variety of functions in the construction industry. Wood is an ineffective water barrier; concrete is used primarily where great strength is required; and steel, which is an adequate sheetpile wall when used for groundwater cutoff, is the most cost-effective material available.

Steel sheetpiles are thin-walled, interlocking sections that are driven into the ground by pneumatic, steam, or vibratory piledrivers. They are manufactured in a variety of shapes and steel strengths. Lengths of the piles vary from 1.2 to 12 meters, while typical widths range from 38 to 51 centimeters. Longer lengths are available by special order.

C.1.3.3 Applicability

Barrier walls might be appropriate as a possible corrective action at the Savannah River Laboratory (SRL) seepage basins, the Separations Area retention basins, the radioactive waste burial grounds, the F-Area seepage basins and



Source: Adapted from EPA, 1982.

Figure C-8. Grout Curtain

the H-Area seepage basins. The following factors limit their applicability to other SRP waste sites:

- Many SRP waste sites are located over groundwater divides. This precludes the application of upgradient barriers and generally requires the use of expensive circumferential barriers.

- Great depths would be required to reach an effective confining stratum for the application of fully penetrating barrier walls. For example, a cutoff wall approximately 46 meters deep, anchored into the Congaree Formation, was required to prevent seepage through the recently constructed L-Reactor cooling lake.

- Generally, partially penetrating barriers are applied to control lighter-than-water contaminants, especially oil. SRP sites that have received oil, such as the waste oil basins, the L-Area oil and chemical basin, and the SRL oil test site, are not likely to require any groundwater remedial action.

C.1.3.4 Summary

Groundwater pumping appears to be a more applicable corrective action at the SRP than either permeable treatment beds or barrier walls for the following reasons:

- Groundwater pumping has already been demonstrated to be effective in containment and subsequent treatment of M-Area groundwater.

- Depths to confining layers (aquitards) are great over most of the SRP, thus requiring extensive excavation and disposal of potentially contaminated soil around certain existing waste sites.

- Permeable treatment beds of several different materials would be required to treat groundwater at many sites because of the mixed composition of the groundwater (i.e., sites that have demonstrated a migration of contaminants usually contain more than a single contaminant). A single bed usually is not effective in removing more than one kind of contaminant.

- The capacity of permeable treatment materials eventually becomes exhausted. In situ regeneration is not feasible. The replacement of an exhausted bed requires the subsequent disposal of the bed.

C.2 DIRECT TREATMENT OF WASTES

C.2.1 BIOLOGICAL TREATMENT

C.2.1.1 Description

An effective way to treat large quantities of contaminated water is biological treatment, which involves the use of microorganisms to digest organic materials. Principal application of this treatment is for aqueous waste streams; however, some organic liquid-phase treatment is possible. Biological treatment is accomplished by the use of one or two types of microorganisms, aerobic or anaerobic. Treatment is conducted in large lagoons or small reaction vessels or tanks. Contaminated water can be spread over land, which is known as landfarming, or treated in place (as with groundwater).

Biological treatment is a versatile treatment process, although many factors can affect its performance, such as:

- Hazardous or toxic substances that inhibit biodegradation reactions
- Retention time
- Temperature; the ideal range is 10° to 38°C
- Sensitivity to organic loading
- Bioaccumulation

Post-Extraction Technologies

The following sections describe technologies that are appropriate for the treatment of waste streams that have been extracted from the groundwater, have been pumped from a lagoon or surface impoundment, or will be received directly as a process waste stream. Treatment can be done by many small units located throughout the site, or can be treated in a large centralized facility. The latter option is less likely to be affected adversely by a single-source shock loading.

Aerobic treatment of waste depends on the use of aerobic microorganisms supplied with sufficient air or oxygen to digest organic wastes. The reactions occur naturally in stabilization ponds, under controlled conditions in specially designed reaction vessels (digestors), or in lagoons with forced aeration.

Activated Sludge

Activated sludge treatment is a continuous-flow treatment process where microorganisms suspended in the aqueous phase metabolize the organic constituents in the presence of oxygen and nutrients. Digestion of the contaminant results in the conversion of organic molecules into carbon dioxide and water. This process is the most widely used and best-understood biological treatment process.

An activated sludge process is designed according to one of three process types: high rate, conventional, or extended aeration. High-rate systems are used for low-strength waste streams, while conventional systems are used to treat higher levels of BOD and more resistant wastes. Aerated lagoons are used when low BOD levels are accompanied by difficult-to-treat wastes, which require a longer contact time.

Aerated Lagoon

Although primarily an aerobic treatment process, both aerobic and anaerobic processes occur simultaneously in an aerated lagoon. Similar to the activated sludge process, this system uses a continuous-flow aerated basin; however, aeration and mixing are incomplete. Thus, the microorganisms are not entirely suspended throughout the lagoon. Incoming material is treated aerobically; however, as the undigested organics and dying microorganisms settle to the bottom where dissolved oxygen levels are low, anaerobic organisms complete the decomposition.

Trickling Filter

The trickling filter is a fixed bed of rock or plastic used as a support for the growth of a biological film. The film or slime accumulates on the medium as organic wastes are metabolized. As the microorganisms grow, the thickness of the slime layer increases and the oxygen transfer to the inner layers decreases. The microorganisms near the surface enter an endogenous growth phase. The biomass near the surface of the medium begins to lose its ability to attach itself. The flow of water eventually detaches the heavier growths. Treated water and excess biomass are removed by an underdrain system and separated downstream by clarification.

Activated Biofilters

Activated biofilters (ABFs) operate as both attached and suspended growth treatment systems. The filter medium is used to support the attached biofilm, while periodic recirculation allows for a mixing of the biomass and the waste stream. The intermittent aeration serves two purposes: to support the growth of the aerobic organisms and to remove the excess biofilm.

Biological Activated Carbon

Biodegradation on biological activated carbon is a relatively new application of two well-established technologies. This process can be used on waste streams that cannot be treated effectively by either process individually. The process begins with the addition of activated carbon to an activated sludge system.

This system is a combination of fixed film and suspended growth systems (similar to the biofilter). The biomass is suspended in the mixed liquor and also attached to the powdered carbon particles. Adsorption and degradation take place within the same basin. The underflow of settled carbon and biomass is sent to a thermal regenerator where the carbon is regenerated, and the excess sludge is destroyed. The regenerated carbon is then returned to the system for further use.

This treatment system has been effective on waste streams with even significant levels of priority pollutants. Heavy metals removal has also been enhanced.

Anaerobic Treatment Technologies

Anaerobic treatment of waste streams uses faculative and anaerobic microorganisms in an enclosed reaction vessel to achieve organic contaminant digestion. This process is applicable to wastewater treatment; however, it generally is used to treat the heavy organic loadings associated with wastewater sludges.

In-Situ Treatment

Biological treatment processes have been developed that permit the decontamination of contaminated groundwater in place. Bioreclamation is a process in which naturally occurring microorganisms are used to degrade the contaminants in the aquifer. To promote the in situ degradation, constant amounts of oxygen and nutrients must be supplied to the microorganisms. Injection wells normally are used to supply these reactants.

C.2.1.2 Applicability

The biological treatment of groundwater or hazardous waste streams has limited applicability at the SRP. The major organic contaminants observed on the Plant are chlorinated aliphatic compounds, which are among the most refractory to aerobic or anaerobic degradation. The ease with which chlorinated materials are volatilized or sorbed on activated charcoal makes such processes more attractive technically.

Treatment of contaminated water by biological systems can be done under a variety of conditions and contaminant concentrations. Systems are available that will decontaminate water in place by biodegradation, in a centralized treatment facility using aerobic and/or anaerobic organisms, or in a combination of these systems.

C.2.2 CHEMICAL TREATMENT

C.2.2.1 Description

Chemical treatment, the use of chemicals to achieve a desired contaminant removal, detoxification, separation, destruction, or neutralization, is achieved by many commercially available processes. Many waste-specific processes are available; most fall into the following basic categories:

- Oxidation/reduction
- Precipitation
- Liquid/liquid extraction
- Neutralization
- Ion exchange

Oxidation/Reduction

Chemical oxidation and reduction are processes for waste detoxification and destruction. Oxidation is applicable to wastes that are oxidized by chlorine, ozone, hydrogen peroxide, potassium permanganate, and chlorine dioxide. Chemical dechlorination, a specific example of chemical oxidation, can be achieved by ozonation.

Chemical reduction is a process in which the oxidation state of a substance is lowered specifically to treat certain soluble metal ions. The reduction of hexavalent chromium to the trivalent state before precipitation with lime or caustic is an example of one application of reduction technology.

Neutralization

The discharge of extremely alkaline or acidic waste streams can pose a significant threat to the environment. Such streams can be neutralized by many available methods. The goal of such a process is to obtain an effluent that has a pH suitable for discharge within regulatory guidelines and standards, or that will not have a detrimental effect on downstream treatment processes, such as biological treatment.

Precipitation

Chemical precipitation is a well-established process for the removal of inorganic compounds. There are three basic types of precipitation systems: carbonate, hydroxide, and sulfide. Of these, the hydroxide system has found the greatest use. Hydrated lime or sodium hydroxide is used to achieve an alkaline pH.

Precipitation can be used to remove both cations and anions; however, the bulk of its use has been for cation removal. The lime-soda softening process is a typical example of a cation precipitation process. This process is also a good example of the carbonate process.

Hydroxide system precipitation can be used to remove a significant number of soluble metal ions. Metals that form insoluble hydroxide precipitates include iron, aluminum, manganese, trivalent chromium, lead, zinc, copper, mercury, silver, cadmium, and nickel. The hydroxides of these metals are normally precipitated at alkaline pH.

Sulfide precipitation has come into common use only recently in wastewater treatment. It is becoming more widely accepted due to the recent discovery that many metal sulfides are less soluble than the corresponding hydroxides. Two sources of the sulfide are sodium sulfide and ferrous sulfide.

Liquid-Liquid Extraction

Liquid-liquid extraction is a chemical separation process that is used widely to separate two immiscible liquid phases. It has, in the waste treatment field, also been used to treat contaminated soils. The basis of either process involves the use of a solvent to separate a contaminant or group of contaminants selectively from an aqueous phase or soil. In cases of gross water contamination, liquid-liquid extraction is best suited for use when distillation would be difficult because the boiling points of the mixture are too close to permit adequate separation. Following the actual separation, distillation is used (if possible) to separate the contaminate. This permits solvent reuse and the disposal of small volumes of hazardous waste.

Ion Exchange

Ion exchange is a process used to remove ionic species from an aqueous solution. In the process, the ionic species are replaced by ions on the ion-exchange resin. A hydrogen ion is exchanged for a cation, or a hydroxide group for an anion. In many applications, a toxic ion will be present in small amounts with large amounts of a relatively innocuous ion of the same or higher valence. Specific ion-exchange resins have been developed for the removal of specific ions, and the use of these resins should be considered to avoid high resin regeneration costs.

Ion exchange is considered applicable for removal of the following:

- All soluble metallic elements
- Inorganic anions such as halides, sulfates, nitrates, and cyanide
- Carboxylic and sulfonic acids, and some phenols at alkaline pH
- Radionuclides such as cobalt-60, yttrium-90, strontium-90, cesium-134 and -137, plutonium-238 and -239, and uranium-238

The ion-exchange resins, which eventually will become exhausted, can be regenerated or disposed of. The costs of onsite regeneration can be prohibitively high, especially when the site is remote. A system with replacement modules might be desirable so the resins can be regenerated offsite. In addition, the regenerant wastes will contain the removed ions at much higher concentrations than the influent and must be treated further or disposed of properly.

C.2.2.2 Applicability

Chemical treatment methods are effective measures for the remediation of contaminated waters and soils. Table C-2 lists some chemical treatment processes and summarizes their possible applications as remedial actions.

Table C-2. Applicability of Chemical Treatment at SRP

Treatment method	Application
• Oxidation/reduction	Groundwater and surface-water decontamination - Metals - Organic contaminants - Radionuclides
• Neutralization	Process waste streams with extreme pH values
• Precipitation	Groundwater and surface water - Metals - Radionuclides
• Liquid-liquid extraction	Grossly contaminated water and soils
• Ion Exchange	Groundwater and surface water - metals, dissolved solids, inorganic anions, carboxylic and sulfonic acids, radionuclides

TC

C.2.3 PHYSICAL TREATMENT

C.2.3.1 Description

Most of the physical treatment processes are concentration technologies. Large wastewater streams contaminated with small concentrations of wastes are treated to produce a cleaner product and a waste stream. The product stream, or effluent, is a high-flow stream with little residual contamination, while the waste stream is a low-flow stream with high concentrations of contaminants. The effluent should be clean enough for discharge, while the waste stream must be taken to a landfill for disposal or treated and rendered nonhazardous.

Flocculation, Sedimentation

Suspended solids in waste streams inherently contain a wide distribution of particle sizes depending on the type and amount of pretreatment that has occurred. Influent streams can contain particles large enough to be visible, or small enough to be submicroscopic. These particles generally carry an electrical charge (usually negative) which can be used advantageously in removal.

Flocculation and a similar process, coagulation, are physical processes which accomplish removal by agglomerating these similarly charged particles into large settleable particles.

Activated Carbon Adsorption

Activated carbon adsorption is a physical treatment process that has demonstrated efficient chemical removal from aqueous streams by chemical processes. The adsorption process involves the concentration of contaminants on the surface of the carbon by physical and chemical means. Attractive forces that predominate at the carbon surface are the basis for the contaminant removal. Materials that have a relatively low solubility in water, or have large molecules, exhibit good adsorption rates. Pesticides and PCBs are examples of contaminants that fit this description. Compounds that are adsorbed readily by activated carbon include aromatics, ethers, esters, and the larger ketones. Alcohols (except for hexanols), amines, aldehydes, and glycols are not adsorbed readily. Radionuclides such as cobalt-60 and cesium-137 can be removed successfully by this process.

Air Stripping

Volatile organic contaminants are removed readily from contaminated aqueous streams by air stripping. This simple, inexpensive process strips the volatile compounds from the water using air as the transfer medium. Contaminated water is charged into the top of a packed column and cascades over the packing while large volumes of air are forced upward through the column.

This treatment technology is well suited to the treatment of solvents and other volatile compounds that have migrated into aquifers beneath the SRP. Water extracted by wells from the water-bearing zones is treated after collection in an air-stripping tower nearby. Such remedial actions are under way in the A/M-Area.

Filtration

Both radioactive and nonradioactive solids can be separated from a liquid by one of three filtration processes: cake, depth, and surface filtration.

Cake filtration involves the separation of solids from the aqueous phase by passing the liquid through a porous filter medium, such as a cloth filter. This medium allows liquids, but not solid particles, to pass. The process yields a thick filter cake. When the operating pressure of the system increases significantly, the medium must be cleaned or replaced. The concentrated waste is then sent to disposal.

In depth filtration, a bed of porous material is used as the filtration medium. A waste stream passes through the filter, where the solid particles become trapped between the small particles of the bed. Operating pressure is also critical for this filtration type. At a certain pressure the bed must be back-washed to return the bed to its original porosity.

In surface filtration, the liquid is strained. This process is similar to the cake filtration process; however, it differs in that the matrix used for filtration becomes clogged at a much higher rate than that used for cake filtration.

Filtration can be used to remove radioactive and nonradioactive suspended solids. This technology can remove radionuclides that have lower solubilities, that tend to absorb to suspended particles, or that can be coprecipitated with other cations. Alpha emitters, such as uranium-238 and plutonium-238, are radionuclides that might be removed by filtration.

Membrane Filtration

Three filtration processes fall under this heading: microfiltration, ultrafiltration, and reverse osmosis. The applicability of each process is as follows:

- Microfiltration and ultrafiltration - High-molecular-weight inorganic and organic contaminants, uranium-238 and plutonium-238

- Reverse osmosis - Metal ions, low molecular weight organic contaminants, strontium-90, cobalt-60, and cesium-134 and -137

Evaporation

Evaporation is a process in which heat is added to a liquid (usually water) to vaporize it, resulting in the concentration of dissolved or suspended solids or the removal of volatile substances. The concentrated materials must be treated further or disposed of, and the vaporized liquid is released to the atmosphere. Three types of evaporation methods are classified by the mode of heat transfer:

- Indirect - heat source is separated from the solution by physical barrier

- Direct - heat source is applied directly to the solution

- Natural - solar energy or natural diffusion of the solution to air are used to induce evaporation

Evaporation methods are more effective for heavier radionuclides, such as cesium-134 and -137, uranium-238, and plutonium-238. Evaporation is an effective way to reduce tritium concentrations in basins.

Electrodialysis

This process is used to transfer an ionic species from one stream of liquid, through a semipermeable membrane, into another stream of liquid under the influence of an applied electrical potential. The process depends on special synthetic membranes that are permeable to a single type of ion. Cation exchange membranes permit passage only of positively charged ions, and anion exchange membranes permit the passage only of negatively charged ions, under the influence of the electrical field.

C.2.3.2 Applicability

Physical or chemico-physical treatment processes have limited applicability for the treatment of contaminated groundwater at the SRP. Air stripping of volatile organic compounds, already in use in the A/M-Area, ion exchange for the removal of soluble metals and radionuclides, and carbon adsorption for the removal of volatile and semivolatile organic compounds offer the greatest feasibility. Centralized treatment facilities might be advantageous.

C.3 CLOSURE

Site closure techniques and methods are designed to reduce surface-water infiltration, to control runoff at waste disposal sites, to reduce erosion, to stabilize the surface of covered sites, and to control leachate generation. Closure techniques include capping, grading and revegetation, runoff diversion and collection, and leachate control systems.

C.3.1 SURFACE SEALERS AND CAPS

C.3.1.1 Description

Surface sealing or capping is used to cover or close a waste site. It prevents surface-water infiltration, isolates contaminated wastes and gases, controls erosion due to surface-water runoff, and provides a surface for vegetation. The process of surface sealing consists of covering the site with a layer or system of layers of natural soils, modified soils, and synthetic membranes. Other techniques use chemical sealants and stabilizers. The choice of the covering material is influenced by such site-specific variables as type of soils, availability and costs of materials, climate and hydrogeology, designed function of the cap, nature of the covered wastes, reliability of the covering material, and projected future life of the site.

Clay

Compacted soils are used commonly for surface sealing or capping. The capacity of a soil cap to resist fluid infiltration is primarily a function of the permeability of the soil material. Clays consist of fine particles with low permeabilities. Clays are susceptible to cracking and dessication, which can reduce their capacity to resist penetration. Therefore, they often are installed as caps in conjunction with covers comprised of other soils or materials (see the paragraph on Multimedia Cap below).

Synthetic Membranes

Synthetic membranes are manufactured covers, commonly made of plasticized polyvinyl chloride (PVC), polyethylene, and butyl rubber. They consist of a raw polymer and carbon black, pigments, fillers, plasticizers, chemicals, and processing aids.

Admixed Materials

Various admixtures can be combined with soil *in situ* to be used as covers for hazardous waste sites. Admixtures include such materials as Portland cement, bituminous concrete, soil cement, soil asphalt, and blown asphalt. All these types of covers are relatively expensive and usually require special mixing or spreading techniques.

Chemical Sealants/Stabilizers

Chemical sealants and stabilizers can be added to soils to form strong and less permeable covers for waste sites. The most common sealant/stabilizers are cement, fly ash, lime, soluble salts, and freeze-point suppressants. Portland cement can be added to sandy soils in quantities as small as 1 percent to stabilize and reduce the permeability of the soils. Soil is treated chemically by the addition of lime. The addition of 2 to 8 percent lime will strengthen fine cohesive soils over time due to the chemical reaction of the lime with clay minerals. Lime also will increase the cementing properties of the clay and reduce shrinking and swelling.

The combination of fly ash, lime, and water forms a cementing compound that can be added to sands and gravels for strengthening and stabilizing effects. It optimizes grain size distribution and reduces shrinking and swelling. Soluble salts like sodium chloride and tetra-sodium pyrophosphate are added to fine-grained soils containing clay minerals to act as dispersing agents. They can break down the clayey aggregates into separate particles (deflocculate) and thereby increase density, facilitate compaction, and lower the permeability of the soil. A freeze-point suppressant such as calcium chloride can be very effective in solution or in dry, flaked form. A suppressant is used on poorly compacted soils during cold weather operations to reduce the potential of the pore water from freezing.

Multimedia Cap

A multimedia cap combines two or more distinct materials in multiple layers that perform specific functions. This cover is the preferred option under the Resource Conservation and Recovery Act (RCRA) and is sometimes called a RCRA-type cap.

A RCRA cap has a top soil layer to support vegetation; a water drainage channel or layer to provide an exit for water; a barrier layer or membrane to prevent infiltration and percolation of water; a buffer layer to protect the barrier by providing a smooth base; a filter layer to control the clogging of coarse layers; and a gas drainage layer. Figure C-9 shows typical layered or multimedia cover systems.

The barrier layer is the most important feature in a multimedia cap. This layer or membrane, which controls the passage of water and gases, is usually a clayey soil with low permeability or a synthetic membrane. The principal purpose of a buffer layer is to protect the barrier layer, shielding it from tears, cracks, offsets, and punctures. The water drainage channel or blanket provides a path for water to exit quickly; recommended soils for this layer are poorly graded sands and gravels. This channel is sometimes combined with a system of buried pipe drains. Filters are used to reduce the clogging of pores in the drainage layer by fine particles of another layer; the selection of a filter material depends on the nature of material being filtered. A gas drainage layer has a structure and function very similar to the water drainage layer; the gas layer is below the barrier layer so it can collect gases rising

Section View

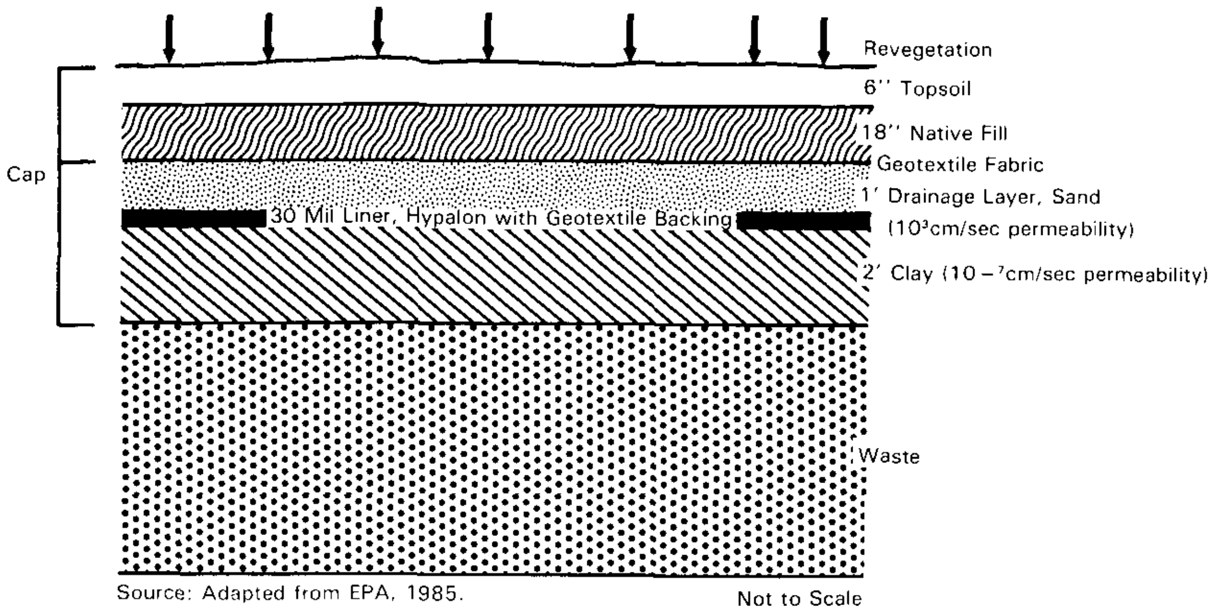


Figure C-9. Multimedia (RCRA) Cap

from the wastes, while the water layer is above the barrier layer to intercept water migrating from the surface.

C.3.1.2 Applicability

The waste sites on the SRP, where modeling results indicate a delay or reduction in peak contaminant concentrations, could be retrofitted with one of the surface sealers or caps described above. The particular system used would be considered on a site-by-site basis. The multimedia cap might make an excellent cover for use on the SRP.

C.3.2 SURFACE-WATER DIVERSION AND COLLECTION SYSTEMS

C.3.2.1 Description

Surface-water diversion structures and collection systems provide either temporary or permanent measures to control surface flows into a hazardous or radioactive waste site. They control flooding and surface-water infiltration. The types of diversions and collectors include dikes and berms, open channels, terraces and drainage benches, chutes, and seepage basins.

Dikes and Berms

A dike or berm (these names are interchangeable) is a well-compacted earthen embankment of low-permeability, erosion-resistant, fine-grained soils. It is positioned above, below, or around the perimeter of a disposal site to intercept and divert surface water. An effective dike or berm thereby reduces erosion potential and prevents excess runoff from entering the site and infiltrating the fill.

Open Channels, Diversions, Waterways

An open channel or swale is an excavated drainageway used to intercept and divert surface water. Such a structure is usually temporary and typically stays in place until the site is sealed and stabilized. A channel upslope of the site can intercept surface water and divert flow; a channel below the site can collect and transport sediment-laden flow to holding basins.

Diversions are shallow drainageways excavated along a contour of graded slopes, with a dike along the downhill edge of the drain. In essence, a diversion is a combination of a dike and a channel that is designed to provide a more permanent control of erosion on long slopes that are exposed to heavy surface water flows. It can be at the top or at the base of long graded slopes of a site to intercept and carry flow. Diversions should be used only for slopes of 15 degrees or less.

A grassed waterway is a wide drainageway that has been stabilized with vegetation or stone riprap. It is usually positioned along the perimeter of a disposal site located within the natural slopes. A waterway is designed to collect and transfer surface water diverted from berms or diversions. A grassed waterway can be part of the final grading design for a capped and revegetated site.

Terraces or Drainage Benches

Terraces or drainage benches are located along the contours of long and steep slopes. They slow down the surface water and divert it to channels or diversions. These benches are considered to be "slope-reducing devices." They should be compacted and stabilized with vegetation.

A terrace is capable of isolating a site hydrologically, reducing erosion on covers, and containing contaminated sediments eroded from the site. An upslope terrace can slow and divert stormwater; a downslope terrace can intercept sediments and divert them to basins.

Chutes and Downpipes

Chutes and downpipes are drainage structures located downslope from dikes. They transfer concentrated runoff from an upper level to a lower level while controlling erosion.

Chutes (or flumes) are open channels lined with bituminous concrete, Portland cement, or grouted riprap. They should be on undisturbed soil or well-compacted fill.

Downpipes, also called downdrains or pipe-slope drains, are located downslope of a site. They are made of corrugated metal pipe or flexible plastic tubing. They collect discharge and transport the flow to stabilized outlets or traps. Because they have limited capacities, they can accommodate only low discharges. A downpipe can collect and transfer surface water from long, isolated outslopes or from small sites along steep slopes.

Seepage Basins and Seepage Ditches

Seepage basins and ditches intercept water from surface-water diversions or groundwater pumps and discharge it back to the groundwater by letting it seep through the ground. Such structures have a basin or ditch, a sediment trap, a bypass for excess surface water, and an emergency overflow. They are lined with gravel at the bases and have pervious material for the side walls. A seepage basin is uncovered, while a seepage ditch is backfilled with gravel or topsoil. Seepage ditches are used in parallel to increase seepage, and they can distribute water over a larger area than basins. Seepage basins use gabions for vertical side walls and dense turf for the side slopes to prevent erosion and allow infiltration.

C.3.2.2 Applicability

Any of the surface-water diversion and collection systems described above could be implemented readily on the SRP. The relatively gentle slope found throughout the Plant has the effect of reducing runoff velocities and concentrations. At most sites, a properly designed and installed cover or cap should be sufficient to minimize the infiltration of water into a waste site. The need for additional protection measures such as surface-water diversion and collection systems would be reviewed during the predesign phase.

C.3.3 LEACHATE CONTROL SYSTEMS

C.3.3.1 Description

Leachate control systems prevent surface-water seepage and leachate from percolating to the groundwater. Leachate is the contaminated liquid that results when surface water migrates down through layers of a landfill and contacts the wastes. The leachate travels to the ground below or seeps from the sides of the fill. A control system intercepts the leachate before it becomes a contamination problem. A system is a series of drains that intercept and channel the leachate to a sump, a wetwell, or a collection basin.

Subsurface Drains

Subsurface drains intercept leachate and transport it away from a site. They are constructed by excavating a trench and laying underground tile or perforated piping from end to end. The pipe is surrounded with an envelope of sand, gravel, and straw, woodchips, or fiberglass. The envelope is lapped with a filter fabric to prevent fine soil from clogging the drain. The trench is closed by a backfill of topsoil or clay.

Drainage Ditches

Drainage ditches are open ditches 1.8 to 3.6 meters deep that can be trapezoidal in cross-section. They collect surface-water runoff, and are collectors leading from subsurface drains or interceptor drains.

Drainage ditches might be required for flat or gentle rolling landfills that have impermeable soils underneath, thereby making the use of subsurface drainage impractical. In some cases, these open drains are used to intercept subsurface collectors and transfer the leachate to a discharge point. Open ditches can collect lateral surface seepage from a disposal site and prevent it from seeping into the groundwater or from flowing into protected areas.

Liners

Liners are used in new or existing sites to intercept leachate before it reaches the groundwater. They are located beneath the fill and act as impermeable barriers. Prefabricated liners, pressure-injected grouts, and bentonite slurry can all be used as bottom sealants, but prefabricated liners are used only in new sites.

C.3.3.2 Applicability

Leachate control systems and components are applicable primarily to new disposal facilities.

C.3.4 SUMMARY

All the closure techniques, both surface-water controls and leachate controls, described in the previous sections can be summarized in terms of functions. These methods primarily reduce surface-water infiltration, control runoff, reduce erosion, discharge water, and intercept leachate. Table C-3 summarizes the individual techniques with their functions.

Table C-3. Closure Techniques and Functions

Technique	Function						
	Minimize runoff	Minimize infiltration	Control erosion	Isolate & contain wastes	Collect & transfer water	Discharge water	Intercept & transport leachate
Surface seals & caps		X	X	X			
With vegetation	X	X	X				
Dikes/berms	X	X	X				
Ditches/diversions/ waterways	X	X	X				
Terraces/benches	X		X				
Chutes/downpipes			X		X		
Leachate controls							X
Seepage basins & seepage ditches						X	